Dietary Patterns and the Metabolic Syndrome in Obese and Non-obese Framingham Women

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Abstract

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Objectives: To examine the relationship between habitual dietary patterns and the metabolic syndrome (MetS) in women and to identify foci for preventive nutrition interventions.

Research Methods and Procedures: Dietary patterns, nutrient intake, cardiovascular disease (CVD), and MetS risk factors were characterized in 1615 Framingham Offspring-Spouse Study (FOS) women. Dietary pattern subgroups were compared for MetS prevalence and CVD risk factor status using logistic regression and analysis of covariance. Analyses were performed overall in women and stratified on obesity status; multivariate models controlled for age, apolipoprotein E (*APOE*) genotypes, and CVD risk factors.

Results: Food and nutrient profiles and overall nutritional risk of five non-overlapping habitual dietary patterns of women were identified including Heart Healthier, Lighter Eating, Wine and Moderate Eating, Higher Fat, and Empty Calories. Rates of hypertension and low high-density lipoprotein levels were high in non-obese women, but individual MetS risk factor levels were substantially increased in obese women. Overall MetS risk varied by dietary pattern and obesity status, independently of *APOE* and CVD risk factors. Compared with obese or non-obese women and women overall with other dietary patterns, MetS was highest in those with the Empty Calorie pattern (contrast p value: $p < 0.05$).

Discussion: This research shows the independent relationship between habitual dietary patterns and MetS risk in FOS women and the influence of obesity status. High overall MetS risk and the varying prevalence of individual MetS risk factors in female subgroups emphasize the importance of preventive nutrition interventions and suggest potential benefits of targeted behavior change in both obese and non-obese women by dietary pattern.

Key words: dietary patterns, risk factor, diabetes, genetic phenotype, cardiovascular disease

Introduction

The rates of cardiovascular disease (CVD)[1] and diabetes rise dramatically in adult women in the presence of the metabolic syndrome (MetS), a clustering of three or more of the following biological risk factors: abdominal obesity, insulin resistance, dyslipidemia [high triglycerides (TGs) and low high-density lipoprotein (HDL)-cholesterol], and elevated blood pressure (1–4). Among the Framingham female and male populations, MetS has been associated with 20% of CVD events and over one-half of recently diagnosed type 2 diabetes during 8 years of follow-up (5). Additionally, the majority of coronary heart disease cases in women <65 years of age occur among those with MetS or multiple CVD risk factors, and diabetes risk rises over 10-fold in women with MetS (4,5).

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[1] Nonstandard abbreviations: CVD, cardiovascular disease; MetS, metabolic syndrome; TG, triglyceride; HDL, high-density lipoprotein; NCEP ATP-III, National Cholesterol Education Program's Adult Treatment Panel III; *APOE*, apolipoprotein E; FOS, Framingham Offspring-Spouse Study; OR, odds ratio; CI, confidence interval.

The prevalence of MetS in women is high (1–3) and, according to the National Health and Nutrition Examination Survey of 1999 to 2000 (6), affects over one-quarter of American women (29.0%). As the obesity epidemic worsens (7), rates of MetS are expected to increase (4,6) and are likely to adversely impact heart disease and diabetes rates among women.

The National Cholesterol Education Program's Adult Treatment Panel III (NCEP ATP-III) (4) has defined MetS as a target for secondary prevention and identifies diet as a key component of treatment. The recommended elements of preventive intervention include a therapeutic diet (low in saturated fat and cholesterol and higher in polyunsaturated-to-saturated fat ratio); carbohydrates derived predominantly from higher-fiber sources (especially whole grains, fruits, and vegetables); weight reduction in persons who are overweight or obese; increased physical activity; and limited alcohol intake. In addition, experts are increasingly calling for research on overall dietary patterns to improve the understanding of the numerous modifiable determinants of disease risk that may guide the development of innovative, focused, and individualized preventive intervention strategies (4,8–10). Furthermore, the exploration of genetic–environmental interactions that may influence individual responses to therapeutic or preventive interventions or risk factor status has received increasing research attention. Several genes, notably apolipoprotein E (*APOE*), are relevant to MetS in that they have been implicated in determining CVD risk status, plasma lipid and glucose levels, and the variability in CVD risk factor responses to dietary interventions, particularly in overweight individuals (11–16).

This research examines the relationship between dietary patterns and MetS in obese and non-obese women, controlling for key biological and genetic covariates, and identifies opportunities for targeted preventive nutrition intervention to reduce MetS risk.

Research Methods and Procedures

Participants

For more than 50 years, the Framingham Study has investigated the natural progression of cardiovascular diseases and, more recently, other health problems among residents of Framingham, MA (17,18). In 1971, a second-generation cohort was recruited, and 5124 Framingham Study offspring and their spouses (2483 men and 2641 women) were invited to participate in the Framingham Offspring-Spouse Study (FOS) (19).

About every 4 years, members of the FOS cohort participate in standardized clinical assessments, including a complete physical exam, laboratory tests, non-invasive diagnostic testing, and updating of medical histories and other pertinent information. At FOS exam 3, 1984 to 1988, we fully characterized the dietary patterns and nutrient intake of Framingham offspring. At exam 4, 1988 to 1992, risk factor profiles of FOS women were evaluated in a manner that allows the full evaluation of MetS risk according to the most recent NCEP expert criteria. Some 2005 women, 18 to 76 years of age, participated at exam 3 (83% of the original offspring cohort women), and 1603 (80% of these women) provided complete data at exam 4 on the MetS and CVD characteristics that we report here. The Boston University Medical Center's Human Subjects Institutional Review Board approved all protocols, and all participants provided informed consent.

Dietary Pattern and Nutrient Intakes

We have published extensively on the identification of five distinct dietary patterns of FOS women (20–22) using validated dietary assessment methods (23,24), expert nutrition guidelines and protocols (25–27), and cluster analysis techniques (28,29). In brief, we classified the 145 Food Frequency Questionnaire items into 38 groupings of foods that were similar to, but more detailed than, those found in the American Dietetic Association's Exchange List for Meal Planning (25,26). The groupings were based on similarities in nutrient content (such as vitamin A–rich vegetables, medium-fat meats, etc.). Next, using standard statistical methods (VARCLUS in SAS) (28), the 38 food groups were clustered based on similarities in their reported frequency of consumption. This resulted in 13 food group clusters; each cluster contained groupings of foods that women reported consuming with similar frequency (i.e., the number of daily servings). It is important to note that this procedure clustered foods together according to their usual frequency of consumption, not according to the time of day eaten or whether they were consumed at the same meal or in similar serving sizes. For example, relative to other women in this cohort, those who reported a higher consumption of fruits also consumed vegetables, lower-fat foods, and whole grain foods more frequently. In the final step, Ward's clustering method (29) was used to separate women into non-overlapping subgroups based on similarities in the frequency of their consumption of the 13 food groupings. Five subgroups of Framingham women, each with a unique habitual eating pattern, emerged from these analyses.

We have reported on the distinct nutrient intake profiles associated with these dietary patterns, their levels of overall nutritional risk, and the stability of FOS women's dietary patterns over 8 years of follow-up (20–22). We have also shown that these dietary patterns are associated with adverse health outcomes in women, notably weight gain and preclinical evidence of cardiovascular disease (30–32).

Risk Factor Measurements and Interpretation

Risk factors are routinely measured at Framingham exams (33) according to extensively published methods, including fasting lipid (33–36) and plasma glucose levels (3);

duplicate blood pressure measurements (21); abdominal obesity (3); self-reported age, smoking, and physical activity; and confirmed menopausal status (30). NCEP ATP III cut-points (4) were used to evaluate study subjects' CVD risk factor characteristics and determine the prevalence of MetS in women overall and in the dietary pattern subgroups.

APOE genotypes

Leukocyte DNA was extracted from 5 to 10 mL of whole blood as previously described (37) and according to current guidelines (38). *APOE* genotyping was performed as described by Hixson and Vernier (39). Three *APOE* genotypes were characterized as follows: 1) *APOE*2 for those subjects carrying the $\epsilon2/\epsilon2$ or $\epsilon2/\epsilon3$ genotypes; 2) *APOE*3 for those carrying the $\epsilon3/\epsilon3$ genotype; and, 3) *APOE*4 for those carrying the $\epsilon3/\epsilon4$ or $\epsilon4/\epsilon4$ genotypes. Because of the contrasting effects of $\epsilon2/\epsilon4$, the small number of subjects bearing this genotype were not included in the analyses.

Analysis

The primary research aim was to examine associations among the habitual dietary patterns of women, individual MetS risk factors, and overall MetS risk, controlling for age, *APOE* status, smoking, physical activity, and menopausal status in all analyses. Stratification on obesity status was based on established relationships between obesity and CVD risk factors. These analyses were restricted to FOS women who were free of diabetes at exam 3. For MetS as an outcome, we calculated the covariate-adjusted proportions for each dietary pattern subgroup and contrasted the Empty Calorie subgroup against all others. The covariates age and physical activity were used in their continuous form, whereas *APOE*($\epsilon2$, $\epsilon3$, $\epsilon4$), smoking (yes/no), and menopausal status (yes/no) were treated as categorical variables. SAS procedure LOGISTIC was employed (28).

In secondary analyses, we examined models contrasting the individual dietary patterns in an attempt to identify whether an "optimal" pattern of habitual intake could be identified. However, none of the dietary patterns was found to be distinctly superior compared with the others in relation to the MetS outcome. We also explored whether energy adjustment altered our findings. The results were consistent with the models without energy adjustment; we present results of the models without energy adjustment to maximize statistical power.

Differences between dietary pattern subgroups on individual MetS risk factors described in their categorical form (elevated glucose, elevated blood pressure, elevated TGs, low HDL-cholesterol, abdominal obesity) were tested using the logistic regression technique. We calculated the "at-risk" proportions for each subgroup. To avoid multiple testing problems, we adopted the following strategy for pairwise comparisons. First, we assessed the significance of the global model using the likelihood ratio test at the level of 0.05. Then we proceeded to test the no subgroup hypothesis using Wald's χ^2 test at the significance level of 0.10, and on rejection, we used the appropriate contrasts to detect pairwise differences at the level of 0.05. The SAS procedure LOGISTIC was used (28).

Results

Mean nutrient intakes and key characteristics of the five distinct dietary patterns of FOS women are summarized in Table 1. Women in the Heart Healthier subgroup had the lowest overall nutrient risk score and were closest to achieving current population dietary recommendations, including higher consumption of dietary fiber, vegetables, fruits, and low-fat milk and lower intakes of total and saturated fat. Lighter Eating women consumed lower levels of most foods and nutrients, as reflected in their lower calorie intakes, including the lowest levels overall of refined grains, soft margarines and oils, and sweets and animal fats. Women with the Wine and Moderate Eating dietary pattern had higher intakes of alcohol, particularly wine, cholesterol-rich foods, high-fat dairy, and snack foods but lower consumption of sweetened beverages (sodas and fruit drinks) and comparatively lower dietary lipid intakes. Women with Higher Fat dietary patterns had the lowest intakes of fruits and low-fat milk and the highest levels of refined grains, soft margarines and oils, sweets and animal fats, and saturated fat. The female Empty Calorie pattern had the highest overall nutritional risk score, as shown in their higher intakes of total fat, calories, and sweetened beverages and lowest intakes of dietary fiber and vegetables.

Table 2 summarizes the relatively high CVD risk in these middle-aged women (mean age, 51.7 years). Rates of hypertension (30.8%) were noteworthy, as were low HDL-cholesterol levels (39.6%) and elevated waist circumference (27.8%). The MetS risk factor profile of obese and non-obese women is presented in Table 3. Obese women had higher rates of all traits compared with non-obese women, as well as higher rates of MetS (51.8% vs. 3.3%, respectively).

Table 4 examines by dietary pattern the proportions of women whose risk factor profiles fail the NCEP ATP-III MetS cut-points. Overall, 16.6% of FOS women had MetS. Abdominal obesity (26% to 38%), low HDL (23% to 52%), and elevated blood pressure (33% to 62%) were particularly high in all dietary pattern subgroups. The low rates of elevated blood glucose (1.3% to 2.1%) reflect the exclusion of women who developed diabetes up to exam 3. MetS ranged from 10.1% to 29.6% across all dietary pattern subgroups and was highest in those with Empty Calorie eating patterns (contrast p value, $p < 0.05$). Women with Wine and Moderate Eating patterns had lower overall MetS rates, lower dyslipidemia (elevated TGs and low HDL-cholesterol levels), and higher rates of hypertension. Heart Healthier and Lighter Eating women had comparatively

Table 1. Age-adjusted selected mean food and nutrient intake by dietary pattern subgroup of FOS women at exam 3 (n = 1265)*†

Nutrients and Foods	Dietary pattern group [mean (95% CI)] Heart Healthier	Lighter Eating	Wine and Moderate Eating	Higher Fat	Empty Calorie
Energy (kcal)	1604^{a} (1548 to 1661)	<u>1515^{b} (1478 to 1552)</u>	1618^{ab} (1473 to 1763)	1609^{a} (1551 to 1668)	**1621^{a} (1526 to 1716)**
Total fat (% energy)	<u>34.5^{b} (33.7 to 35.3)</u>	36.9^{a} (36.4 to 37.5)	35.7^{ab} (33.5 to 37.8)	37.8^{a} (36.9 to 38.7)	**37.9^{a} (36.5 to 39.3)**
Saturated fat (% energy)	<u>11.5^{c} (11.1 to 11.9)</u>	12.8^{b} (12.5 to 13.0)	11.7^{c} (10.8 to 12.7)	**13.7^{a} (13.3 to 14.1)**	13.3^{ab} (12.7 to 13.9)
Polyunsaturated fat (% energy)	7.86 (7.52 to 8.19)	**7.88 (7.66 to 8.10)**	7.64 (6.78 to 8.51)	<u>7.55 (7.20 to 7.9)</u>	7.73 (7.16 to 8.29)
Monounsaturated fat (% energy)‡	<u>12.3^{b} (12.0 to 12.7)</u>	13.4^{a} (13.1 to 13.6)	13.4^{a} (12.5 to 14.3)	13.7^{a} (13.3 to 14.1)	**13.9^{a} (13.4 to 14.5)**
Cholesterol (mg/1000 kcal)	<u>138.7^{b} (130.9 to 146.5)</u>	153.6^{a} (148.5 to 58.7)	**165.0^{a} (144.9 to 185.0)**	147.6^{ab} (139.5 to 155.6)	145.3^{ab} (132.2 to 158.5)
Alcohol (% energy)	2.70^{ab} (2.13 to 3.27)	3.24^{b} (2.87 to 3.61)	**10.4^{c} (8.94 to 11.86)**	2.00^{ad} (1.42 to 2.59)	<u>1.45^{d} (0.49 to 2.40)</u>
Dietary fiber (g/1000 kcal)	**9.9^{c} (9.5 to 10.2)**	8.4^{b} (8.1 to 8.6)	8.1^{ab} (7.1 to 9.1)	7.9^{a} (7.5 to 8.3)	<u>7.3^{a} (6.6 to 7.9)</u>
Nutrient risk score§	<u>561^{b}</u>	644^{a}	661^{ac}	662^{ac}	**679^{c}**
Food groups (servings/d)					
Vegetables	**3.91^{b} (3.70 to 4.11)**	2.59^{a} (2.51 to 2.67)	3.16^{c} (2.80 to 3.52)	2.75^{a} (2.61 to 2.88)	<u>2.55^{a} (2.33 to 2.77)</u>
Fruits and low-fat milk	**4.33^{b} (4.10 to 4.56)**	2.45^{a} (2.36 to 2.54)	2.44^{a} (2.07 to 2.82)	<u>2.39^{a} (2.23 to 2.54)</u>	2.56^{a} (2.31 to 2.80)
Refined grains, soft margarine, and oils	3.42^{a} (3.23 to 3.61)	<u>2.60^{b} (2.51 to 2.71)</u>	2.86^{bc} (2.41 to 3.32)	**3.66^{a} (3.42 to 3.91)**	2.96^{c} (2.67 to 3.24)
Sweets and animal fats	1.12^{b} (0.99 to 1.24)	<u>1.05^{b} (0.98 to 1.12)</u>	1.75^{c} (1.28 to 2.23)	**4.45^{a} (4.22 to 4.68)**	2.49^{d} (2.16 to 2.82)
Sweetened beverages	0.30^{ab} (0.25 to 0.35)	0.27^{b} (0.24 to 0.30)	<u>0.23^{ab} (0.15 to 0.31)</u>	0.34^{a} (0.29 to 0.39)	**2.74^{c} (2.58 to 2.90)**
Wine and cholesterol-rich foods	0.43^{b} (0.39 to 0.46)	0.46^{b} (0.43 to 0.48)	**2.77^{c} (2.66 to 2.89)**	0.36^{a} (0.33 to 0.39)	<u>0.34^{a} (0.30 to 0.39)</u>
High-fat dairy and snack foods	0.69^{a} (0.64 to 0.75)	0.78^{b} (0.73 to 0.82)	**0.92^{b} (0.76 to 1.08)**	<u>0.67^{a} (0.62 to 0.71)</u>	0.79^{b} (0.70 to 0.88)

* A total of 1265 women provided complete 3-day dietary records for estimation of nutrient intake.

† 1828 women completed the Food Frequency Questionnaire for cluster analysis from which food groups were derived.

‡ Monounsaturated fat is primarily from animal fat (lard) and not olive or other vegetable oils.

a,b,c,d Means with different superscripts are significantly different from each other; means that are underlined are lowest; means that are bold are highest.

§ Nutrient risk score—overall nutrient risk score based on the consumption of 19 nutrients by members of one dietary pattern subgroup. Scores were obtained by ranking the nutrient intake levels for each person in the cohort; a lower rank was assigned for a desirable intake level (e.g. lower fat or higher vitamin/mineral intake) and a higher rank for a less desirable intake level (e.g. higher fat or lower micronutrient intake). The overall mean rank of the dietary pattern group was computed from the sum of the mean ranks of the 19 nutrients for each woman in that subgroup. Nutrients that were considered included energy, protein, total fat, monounsaturated fat, polyunsaturated fat, saturated fat, alcohol, cholesterol, sodium, carbohydrate, fiber, calcium, selenium, vitamin C, vitamin B_6, vitamin B_{12}, folate, vitamin E, and β-carotene.

Table 2. Risk factor profile of FOS Women at exam 4 ($n = 1603$)*

Risk factor	Mean ± SD	NCEP criteria†	Percentage
Age (years)	51.7 ± 9.9	≥55	40.7
Systolic blood pressure (mm Hg)	124.8 ± 19.6	≥130	36.4
Diastolic blood pressure (mm Hg)	76.9 ± 9.6	≥85	22.1
Hypertension (yes/no)‡	–	Yes	30.8
Diabetes (yes/no)	–	Yes	5.2
Cigarette smoking (yes/no)	–	Yes	23.0
Total cholesterol (mM/L)§	5.4 ± 1.1	≥6.2	20.1
HDL-cholesterol (mM/L)§	1.4 ± 0.4	<1.3	39.6
LDL-cholesterol (mM/L)§	3.4 ± 1.0	≥4.1	19.2
TGs (mM/L)§	1.3 ± 1.2	≥1.7	18.5
Glucose (mM/L)§‡	5.2 ± 1.3	≥6.1	6.5
Waist circumference (cm)	81.6 ± 13.3	>88	27.8

* Sample includes women with complete risk factor data at exam 4.
† Reference 4.
‡ Hypertension based on NCEP criteria: blood pressure ≥ 140/90 mm Hg or on antihypertensive medication.
§ From fasting blood samples.

high rates of elevated blood pressure, high TGs, and abdominal obesity. Women with the Higher Fat dietary pattern had more problematic HDL levels but relatively lower (albeit high) rates of hypertension and abdominal obesity.

Table 5 contrasts MetS profiles in non-obese and obese FOS women by dietary pattern. MetS risk varied in non-obese and obese women across the dietary pattern subgroups but rose substantially in obese women. The Empty Calorie dietary pattern was associated with the greatest overall MetS risk in both obese and non-obese women (contrast p value, $p < 0.05$), but MetS affected nearly three-quarters (72.7%) of obese women. Low HDL levels were also more prevalent in obese women with Empty Calorie dietary patterns (77.1%).

Table 3. Age-adjusted prevalence of MetS factors by obesity status in FOS women at exam 4 ($n = 1533$)*

		Risk factor prevalence (%)	
Risk factor	NCEP criteria†	Non-obese ($n = 1138$)	Obese ($n = 395$)
Glucose (mM/L)‡	≥6.1	0.7	4.2**
Blood pressure (mm Hg)§¶	≥130/≥85	32.5	60.1**
TGs (mM/L)‡	≥1.7	9.3	31.7**
HDL-cholesterol (mM/L)‡	<1.3	32.8	65.1**
MetS	≥3 risk factors	3.3	51.8**

* Sample includes non-diabetic women with complete risk factor data at exam 4.
† Reference 4.
‡ From fasting blood samples.
§ Blood pressure cut-points are a combination of systolic and diastolic measurements.
¶ Proportion with elevated blood pressure includes those on antihypertensive medication.
** $p < 0.0001$.

Table 4. Multivariate-adjusted prevalence of MetS factors at exam 4 in FOS women by dietary pattern group*

	Risk factor prevalence (%)					
Risk factor for MetS (NCEP criteria)	**All women (n = 1533)**	**Heart Healthier (n = 302)**	**Lighter Eating (n = 729)**	**Wine and Moderate Eating (n = 55)**	**Higher Fat (n = 313)**	**Empty Calorie (n = 134)**
Blood glucose (≥6.1 mM/L)†	2.4	**2.1**	1.5	1.5	1.3	1.9
Blood pressure (≥130/≥85 mm Hg)‡§	41.3	46.4[a]	36.5[b]	**61.6**[a]	32.6[b]	49.1[a]
TGs (≥1.7 mM/L)†	16.1	15.2	14.5	5.9	12.9	**19.8**
HDL-cholesterol (<1.3 mM/L)†	41.1	38.6[ab]	39.0[b]	23.1[c]	47.3[ad]	**52.2**[d]
Abdominal obesity (waist circumference >88 cm)	25.8	27.8	28.3	31.9	25.6	**38.3**
Proportion with three or more of the above	16.6	15.2	14.7	10.1	14.9	**29.6**¶

* Covariates include age, *ApoE*, smoking, physical activity, and menopausal status. Model includes women who were clustered into dietary pattern subgroups and for whom there were complete data on MetS risk factors and covariates (n = 1268). Diabetic women were excluded.
† From fasting blood samples.
‡ Blood pressure cut-points are a combination of systolic and diastolic measurements.
§ Proportion with elevated blood pressure includes those on antihypertensive medication.
[a,b,c,d] Mean proportions (%) with different superscripts are significantly different from each other ($p < 0.05$); mean proportions that are underlined are lowest; mean proportions that are bold are highest.
¶ Contrast between Empty Calorie dietary pattern subgroup and all others is significant ($p < 0.05$).

Discussion

MetS varied by dietary pattern in FOS women overall, as well as in obese and non-obese female subgroups, independently of age, *APOE* genotype, smoking, physical inactivity, and menopausal status. Compared with other habitual dietary patterns, MetS was most prevalent in non-obese and obese women with the Empty Calorie dietary pattern. Both obese and non-obese women in this subgroup also had relatively higher rates of dyslipidemia. Of note are the prevalent hypertension, dyslipidemia, and abdominal obesity in all dietary pattern subgroups. These findings underscore the adverse health impact of MetS on women and suggest that benefits may accrue if favorable changes are made in the habitual dietary patterns of those who are non-obese and obese. Furthermore, this research suggests that obese women who are unable to achieve recommended weight goals may benefit from dietary pattern changes to reduce MetS risk.

These research findings are consistent with our earlier research on the Empty Calorie dietary pattern in relation to other health outcomes. In a study of 1423 FOS women (31) who were free of CVD at exam 3 and followed for 12 years, the Empty Calorie dietary pattern was associated with a >2-fold risk of carotid stenosis (a preclinical marker of systemic atherosclerosis) in comparison with referent Heart Healthier women [odds ratio (OR), 2.28; 95% confidence interval (CI), 1.12, 4.62; $p < 0.05$). In an earlier study of 737 FOS women who were non-overweight at FOS exam 3, 22% to 30% of women became overweight (BMI > 25 kg/m^2) over 12 years of follow-up, depending on their dietary pattern. Compared with the referent Heart Healthier women, those with the Empty Calorie dietary pattern had, numerically, the highest multivariate-adjusted risk for developing overweight. Multivariate modeling somewhat attenuated the statistical significance of these results (relative risk, 1.4; 95% CI, 0.9, 2.2) (30).

Other researchers have also observed relationships between dietary patterns of women and disease end-points, notably coronary heart disease (40) and colon cancer (41). There is also limited population research on selected MetS risk factors and dietary patterns. Maskarinec et al. (42) found three of the four dietary patterns of Hawaiian women to be associated cross-sectionally with BMI. The meat dietary pattern (high in animal products) was associated with

Table 5. Multivariate-adjusted prevalence of MetS risk factors by dietary pattern group in nonobese and obese FOS women*†

Risk factor for MetS (NCEP criteria)	Risk factor prevalence (%)									
	Non-obese					Obese				
	Heart Healthier (*n* = 220)	Lighter Eating (*n* = 547)	Wine and Moderate Eating (*n* = 40)	Higher Fat (*n* = 238)	Empty Calorie (*n* = 93)	Heart Healthier (*n* = 82)	Lighter Eating (*n* = 182)	Wine and Moderate Eating (*n* = 15)	Higher Fat (*n* = 75)	Empty Calorie (*n* = 41)
Blood glucose (≥6.1 mM/L)‡	**0.01**	0.00	0.00	**0.01**	**0.01**	6.2	4.8	**7.5**	4.4	4.5
Blood pressure (≥130/≥85 mm Hg)§¶	35.9^{ac}	27.7^{bc}	**53.9**^{a}	24.0^{b}	38.5^{ac}	72.5	61.7	**78.9**	58.0	68.2
TGs (≥1.7 mM/L)‡	8.6	7.8	4.3	3.7	**9.1**	32.0	32.3	8.6	**40.8**	38.6
HDL-cholesterol (<1.3 mM/L)‡	32.2	30.0	17.4	36.8	**39.2**	55.5^{a}	64.3^{ab}	38.8^{a}	75.1^{b}	**77.1**^{b}
Proportion with ≥3 of the above	2.1	1.6	0.0	0.9	**5.0**	49.4	51.2	40.5	59.4	**72.7****

* Obesity is defined by a waist circumference of >88 cm.
† Covariates include age, *ApoE*, smoking, physical activity, and menopausal status. Model includes women who were clustered into dietary pattern subgroups and for whom there were complete data on MetS risk factors and covariates ($n = 1268$). Diabetic women were excluded.
‡ From fasting blood samples.
§ Blood pressure cut-points are a combination of systolic and diastolic measurements.
¶ Proportion with elevated blood pressure includes those on antihypertensive medication.
^{a,b,c} Mean proportions (%) with differing superscripts are significantly different from each other ($p < 0.05$); mean proportions that are underlined are lowest; mean proportions that are bold are highest.
** Contrast between Empty Calorie dietary pattern subgroup and all others is significant.

higher BMI levels ($r = 0.17$, $p = 0.0001$), whereas the bean (high in legumes and tofu) and cold foods (higher in fruits and cereal) dietary patterns were associated with lower BMI levels ($r = -0.13$, $p = 0.003$ and $r = -0.13$, $p = 0.003$, respectively). Wirfalt et al. (43) identified six dietary patterns among male and female participants of the Malmo Diet and Cancer study and found cross-sectionally that the risk of hyperinsulinemia was lower in women with the Milk-fat pattern (high in "Bregott" spread; OR, 0.66; 95% CI, 0.48, 0.91). In men, Many Foods and Drinks (higher in cheese, fat meat, cake, and fruits) was associated with a higher risk of hyperglycemia (OR, 1.79; 95% CI, 1.40, 2.29), and the Fiber Bread pattern (high in fiber-rich bread) was associated with a lower risk for central obesity (OR, 0.58; 95% CI, 0.41, 0.81). A recent prospective study adds important information on the relationship between dietary patterns and changes in MetS risk factors, including changes in BMI and waist circumference. Newby et al. (44) characterized and contrasted five dietary patterns among male and female Baltimore Longitudinal Study of Aging participants: Healthy (high in high-fiber cereal, fruits, reduced-fat dairy), White Bread (high in white bread), Alcohol (high in alcohol), Sweets (high in sweets), and Meat and Potatoes (higher in meat, potatoes, fast food, and non-diet soda). Participants with the Healthy dietary pattern had the least gains in BMI and waist circumference. The Meat and Potatoes and the White Bread patterns were particularly detrimental in terms of changes in BMI or waist circumference in comparison with the Healthy pattern. The mean annual BMI change was 0.05 ± 0.06 kg/m^2 in the Healthy cluster and 0.30 ± 0.06 kg/m^2 in the Meat and Potatoes cluster ($p < 0.01$). Subjects in the White Bread pattern had a mean annual change in waist circumference of 1.32 ± 029 cm compared with 0.43 ± 0.27 cm in the Healthy pattern ($p < 0.05$).

In this report, the prevalence of MetS was lowest among women in the Wine and Moderate Eating dietary pattern. While this relationship seems favorable, it seems to be driven by the higher HDL-cholesterol and lower TG levels of these women. Nonetheless, the higher rates of elevated blood pressure, regardless of obesity status, and the higher blood glucose levels of the obese women within this habitual dietary pattern raise concerns over its overall health impact. Our previous research has suggested that women with Wine and Moderate Eating behavior may be at somewhat higher risk for the development of carotid stenosis (31) compared with referent Heart Healthy women, although the risk for developing overweight in lean women who favor this dietary pattern may be lower than that of women with other dietary patterns (30).

The importance of research on dietary patterns and health outcomes has been increasingly examined in the literature (8,9,45,46). The dietary pattern approach is viewed as a means of identifying specific aspects of diet-related behavior that can be used to focus health-related messages, which consumers may be more likely to act on (8). Consistent with this approach, NCEP investigators (45) have urged advances in epidemiological and clinical research to provide information that can be used to design behaviorally based nutrition interventions.

The dietary patterns we describe here are habitual in nature, and none represented an ideal intake compared with expert nutrition guidelines. Each pattern (Table 1) suggests targets for preventive intervention to lower MetS risk and to achieve current preventive nutrition recommendations (increase high-fiber carbohydrate sources, lower saturated fat and dietary cholesterol levels, increase polyunsaturated:saturated fat ratio, and limit alcohol intake). Strategies for women with the Empty Calorie dietary pattern could focus particularly on the reduction in foods with hidden fats and sweets (including soft drinks and other sweetened beverages and desserts) and increases in vegetable intake. Women with Lighter Eating behavior could strive for portion control and nutrient-dense foods that promote balanced nutrient intake. The high level of alcohol intake among women with Wine and Moderate Eating patterns seems important to target, along with their relatively high intakes of cholesterol-rich foods and high-fat dairy products and snacks. The focus for women with Higher Fat eating pattern could be on a reduction in visible animal fats, refined grains, and sweets and increased intakes of fruits, lower-fat foods, and legumes. Heart Healthier women could be encouraged to continue and expand the more favorable aspects of their eating behavior while targeting animal fats and fiber as areas for improvement. All overweight women would likely benefit from weight reduction.

Having stated these overall guiding principles of dietary intervention planning by dietary pattern, we note that comorbidities vary in these subgroups of women and emphasize that MetS risk was closely linked to women's obesity status. For example, the higher rates of hypertension in Wine and Moderate Eating women seem to further raise the importance of alcohol moderation and weight management in those who are overweight. Our previous research (30) indicated that Lighter Eating women were prone to weight fluctuations, possibly a reflection of chronic dieting. Food portion control, increased nutrient-dense food intake, and avoidance of binging–restricting behavior seem to be key facets of preventive nutritional intervention in these women.

The high but varying MetS risk factor levels in obese women in all dietary pattern subgroups raise another issue. Weight loss to ideal levels is certainly optimal, but it may be unrealistic in the long term. These findings suggest that benefits may accrue by shifting to alternative dietary patterns, particularly in Empty Calorie obese women. The Heart Healthier pattern most closely approximates current expert preventive nutrition guidelines, but other dietary patterns were also associated with lower MetS risk (compared with Empty Calorie women). Therefore, other dietary patterns may be more appealing or easier for women to consider as they attempt to improve their eating behaviors.

It is a limitation of this research that we did not follow disease-free FOS women from early adulthood and observe the emergence of MetS over a longer period of time. This is difficult to do under any circumstance but particularly in populations in which obesity rates are epidemic. Also, the results may not be generalizable to minority women, because the Framingham cohort is predominantly white. Furthermore, although this cross-sectional research does not strictly show that diet was a precursor to MetS, it does aid in pinpointing potential strategies for preventive nutrition interventions.

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